Whatever explanation is accepted for the double bond isomerism, the same explanation will apply to the isomerism of the platinum compounds. Werner considers that the explanation of the spatial configuration applies to both. On the other hand, if the double bond isomerism is due to the directions of the valences which is the same as the distribution of the negative electrons in the acids, then the explanation of the isomerism of the platinum compounds should be based upon the distribution of the electrons in the platinum atom. There is, however, only one atom involved here, so that it appears as if this isomerism would furnish a method for showing the distribution or arrangement of the electrons in an atom, or perhaps the spatial configuration of the atom, different arrangements of electrons giving rise to possibilities of the existence of isomeric compounds. It is even possible, and perhaps very probable, that the different arrangements of the electrons might control the spatial positions of the combined groups. The spatial configurations deduced by Werner and others, then would exist, but would actually be an effect of the arrangement of the electrons. The positions of the combined atoms therefore would be a result of the isomerism and not its cause.

These platinum and similar metal compounds would then belong to the class of electromeric substances. Since this explanation means that the spatial arrangement of atoms or groups around a central atom depends primarily upon the spatial arrangement of the valence and also other electrons of that central atom, a further logical deduction would include all optically active isomers in organic and inorganic chemistry in the group of electromers. The spatial arrangements of the atoms or groups here would also be governed or controlled primarily by the arrangement of the electrons of the atom showing the optical activity.

K. GEORGE FALK,
J. M. NELSON
HARRIMAN RESEARCH LABORATORY,
ROOSEVELT HOSPITAL,
COLUMBIA UNIVERSITY

POSSIBILITY OF USING GRAVITY ANOMALIES IN THE SEARCH FOR SALT-DOME OIL AND GAS POOLS

THE immense masses of common salt that have forced their way up toward the surface of the earth in Louisiana, Texas and other low plains regions where there is no hard rock within several thousand feet of the surface, seem to afford all the fascination and baffling questions that can be desired by the structural geologist, though thrilling encounters with such questions are usually sought in mountainous regions. Recorded and available notes on experiences in the sinking of the thousands of wells that have been put down on salt domes in the search for oil is dishearteningly scant, and yet sufficient to give a fair idea of the common extents, positions and shapes of the upper portions of the salt cores. If as much were known concerning their lower portions it might not only be possible to determine their cause and mode of growth with a fair degree of certainty, but to devise means of discovering by gravity observations, hidden domes, for some are scarcely evident from the surface, and perhaps many unsuspected ones with valuable oil and gas pools are scattered through the coastal portions of Louisiana, Texas and other regions.

Are the salt domes due to some process related to volcanic action? The domed form of the strata, which is much more commonly seen than the core itself, is such as might have been produced by a rising plug of igneous rock and even the masses of salt and associated secondary deposits might apparently have been produced indirectly by intrusions. On the other hand, though many very deep wells have been drilled in salt domes, igneous rock has rarely if ever been touched. Since there are numerous varieties of salt domes—some making a

conspicuous hill, some through recent solution of the salt making a depression, and some having little or no effect on the surface, the salt core of some lying at slight depth and of others at great depth—it would appear that if they are due to intrusion, the igneous rock should have been found in some of them.

Furthermore, in areas of igneous activity intrusions have various forms, dikes being common, but salt domes are sharply localized, more or less equi-dimensional laterally, in length and breadth rarely measuring over two or three miles or less than one half mile. Although in an area underlain by a great thickness of unconsolidated strata intrusions may differ somewhat from those of other areas, still, since the country rock, being unconsolidated, is more likely a body of water than if it had been cemented into stone, it seems quite unreasonable to assume that either intrusions or secondary deposits made by circulating waters or gases emanating from them would be similar in form and size and short in lateral dimensions. The fact that salt domes are found on the northwest and southwest coasts of the Gulf of Mexico, and that, due perchance to more consolidated rock, igneous intrusions are common in territory between, invites investigation to determine whether or not gradation phases may be found between salt domes and intrusions. Such phases, however, seem to be poorly developed and the series, if there is one, incomplete. Also, although intrusions have made dome structures and hills on the surface in many parts of the world, no evidence of an overlying salt core seems to have been found.

Are the domes due, as has also been suggested, to forces of crystallization acting in some such way as they do in the growth of concretions, the salt being taken from saturated solutions and collected around some nucleus by molecular attraction? Ordinarily salt does not seem to behave in this way and the associated great deposits of dolomite, gypsum and other secondary substances would seem too much to ascribe to a kind of mass action not controlled by some other set of forces operating at or underneath the locus of salt-dome growth. The apparent lack of concentric structure and of small salt concretions, and the presence of certain minerals, such as sulphur and copper ores, seems to point to a deep-seated cause for the domes.

May the salt domes be due to a buckling and flowage of one or more beds of rock salt lying at great depth, as has been suspected concerning European salt domes or more indirectly to some process of isotatic adjustment? If so some of the salt cores should be connected below with the parent stratum or strata of rock salt, and the average mass of salt perhaps much greater than if it had developed in some other way. However, since the country rock is largely unconsolidated, and, on the whole, homogeneous, and the surface is smooth and horizontal, it would seem rather improbable that the bodies of salt could have been produced through differential pressure, though it must be admitted that a small stress difference operating for a very long time may accomplish a great deal, and once started the process might be somewhat self-accelerating. Also the association of salt, dolomite, gypsum, sulphur, copper, etc., suggests a Permian source. As a matter of fact, however, the few determinations of specific gravity of the country rock that have been made indicate that it weighs in its natural wet state no more than salt, if indeed as much, and it seems very improbable that there has been any considerable horizontal thrust pressure.

In any case from what has been learned by deep boring and from the various conceivable possibilities as to salt dome origin, it seems probable that the known upper portions of salt cores are underlain with (*a*) more salt, (*b*) clay and sand, or (*c*) igneous rock. Although it is possible that the clay and sand strata through which the salt rises, differ more or less markedly from it in specific gravity, the surprisingly little information available on the subject indicates that in their natural state the salt is appreciably the heavier. The writer has tested seven samples of common sandy clay and clayey sand from the Gulf Coast region, and the results indicate that although the specific gravity varies considerably, it is not far

from that of salt. There is a real possibility, however, that the difference is great enough so that large bodies of rock salt not far from the surface can be detected by determinations of the intensity of gravity.

While investigating the "mud lumps" at the mouths of the Mississippi a few years ago the writer had occasion to study isostacy a little, for it seemed probable that the "mud lumps" were due to gravity—induced internal flowage of the delta. The question arose, may not the salt domes be due to some such solid or semi-solid flowage? and another question immediately arose, namely, may not the domes have a perceptible effect on gravity? The domes of southern Texas and Louisiana are in a region that is very flat, and although some domes are marked by knolls from two to three to thirty feet or more in height, some domes that are very high structurally have little or no effect on the surface. Whether this indicates that many domes are antecedent to the surface deposits has not been determined. In any case the means now available for finding domes not marked by a hill or basin on the surface seem to be limited to scant and irregularly developed secondary deposits at the surface, such as the curious "paraffin earth" which is apparently a new compound, though containing possibly both gelatinous silica and some hydrocarbon.

Since the domes are in a flat region underlain by comparatively homogenous sand, silt and clay, it seems more than likely that the salt, dolomite, gypsum, sulphur, compressed clay and possibly igneous rock of the domes would together have a specific gravity noticeably different from that of the country rock in which they occur, and within the range of possibility that the difference could be detected by gravity observations. In other words it seems possible that hidden salt domes, with the immensely valuable pools of oil and gas that are commonly associated, can be discovered through the help of gravity observations, which will thus reduce to a greater or less extent the cost of finding the oil pools.

The intensity of gravity varies with altitude, latitude, topography and the varying density of the materials composing the earth, particularly near the points where the observations are made.

> A mass weighing 200 pounds at sea level at the equator will weigh [on a spring balance] approximately 201 pounds at sea level at either pole. A mass weighing 400 pounds at sea level will weigh approximately 399 pounds at an elevation of 5 miles at the same latitude; and a given mass will weigh less at the top of a sharp mountain peak than if it were at the center of a broad plateau of the same elevation as the peak. . . . The measurement of the force of gravity at a station to be acceptable must not have a probable error greater than one part in two hundred thousand. An actual error of one part in two hundred thousand corresponds to an error of only one one-millionth of a second in the period of oscillation of the pendulum.[1]

The method of observation, consists essentially in determining the effect of gravity on the rate of swing of a pendulum. The instrument "is placed on a solid concrete floor or an especially prepared brick or concrete pier." With the interferometer, vibrations of the case "due to the passing of a team a city block away or a team a mile away are easily detected."

The average probable error in the gravity observations of the Coast and Geodetic Survey is said to be in general about .002 or .003 of a dyne.

> If we assume that the force of gravity at the center of a section [square mile] which is underlain with sand one mile deep at a specific gravity of 2.50 is 980,000 dynes, then if the [cubic mile of] sand were replaced by limestone at a specific gravity of 2.75 the force of gravity would be increased to about 980.005 dynes. Similarly, if the same were replaced by basalt at a specific gravity of 3.00 the force of gravity would be increased to about 980.010 dynes. The change in the force of gravity at the center of the adjacent section due to these changes in specific gravity would be about one fifth as much as in the section affected.[2]

Apparently, if a cubic mile of clay and sand with a specific gravity of 1.80–2.00 immediately

[1] U. S. Coast and Geod. Survey, Spec. Pub. No. 23, pp. 48 and 50, 1916.

[2] Letter to writer from acting superintendent Coast and Geod. Survey, April 4, 1916.

underlying the surface were replaced by common salt with a specific gravity of 2.10 or 2.20, the effect on the intensity of gravity might be observable. If a still heavier mass made up of salt, dolomite, igneous rock, etc., having a specific gravity of 2.50 to 2.75 were intruded the rate of swing of the pendulum would be very perceptibly increased. If, however, only a quarter of a cubic mile of the clay and sand were replaced with the lighter or heavier substances, the effect would scarcely be observable, and if the intrusion occurred several thousand feet below the surface it might not be possible to locate the position with the gravity instrument. Other instruments have been devised for measuring the intensity of gravity that do not make use of the pendulum, and it seems within the range of possibility that in time an instrument of some sort will be perfected by which more delicate observations can be made.

The writer has found but one published statement suggesting the use of gravity anomalies in the search for oil, and this was not intended to apply in the way here outlined. Eötvös,[3] in 1913, suggests that it may be possible to find water, ore, coal, salt, oil and gas by using gravity anomalies. David White[4] has, however, studied the relationships between gravity anomalies and character of rocks.

On account of the slight variations in altitude and latitude in southern Louisiana and Texas and other regions where salt domes occur, it seems possible that a considerable part of the calculations made in connection with the occupation of stations for other purposes may be eliminated. The use of gravity observations in the search for salt domes would then consist essentially in determining at many points the number of beats in a unit of time of a pendulum so constructed and encased as to reduce the friction to the lowest point possible. If the material in many of the domes will perceptibly affect the number of beats then it may be that gravity anomalies can be used profitably in searching for hidden domes, the observations for most points in a county or group of counties being uniform, while at a few points a perceptible departure can be observed. The increasing value of oil and the keen interest in prospecting make it seem possibly worth while to make some practical tests with the gravity instrument on a known salt dome and surrounding country, especially since many wells are being sunk at random in the region. To be sure, some salt domes are known which do not seem to have oil pools, and others are known which have not yet been fully tested, but the number of insufficiently tested domes is rapidly decreasing, and with the keener interest in the search for oil the time will no doubt soon come when it will be profitable to spend a great deal of money searching for salt domes, for they seem to be much more likely to contain oil than the surrounding country.

Eugene Wesley Shaw
U. S. Geological Survey

[3] Eötvös, Roland, Ungarn. Bericht über Arbeiten mit der Drehwage ausgeführt im Auftrage der Kön. Ungarischen Regiergung in den Jahren 1909–1911: Internat. Erdmessung, 17 Allg. Conf., Hamburg, 1912, Beilage *A*, XL., pp. 427–438, 1913.

[4] White, David, "Discussion of Gravity Anomalies from the Stratigraphic Standpoint" (no abstract). Discussed by William Bowie: Washington Acad. Sci. Jour., Vol. 7, No. 10, p. 312, May 19, 1917. Meeting of Geol. Soc. of Washington on March 14, 1917.

ANNUAL FIELD TRIP OF THE AMERICAN ASSOCIATION OF STATE GEOLOGISTS

The American Association of State Geologists made a very pleasant and instructive trip through Oklahoma, October 12 to 16. At the winter meeting in Albany, in December, 1916, it was decided to hold the summer field meeting in Oklahoma, and the Oklahoma Geological Survey accordingly made very comprehensive plans for the entertainment of the association.

The declaration of war and the consequent interest of the geologists in war materials lead to the combination of the first part of the field trip with the meeting of the American Institute of Mining Engineers.

After the meeting of the American Institute of Mining Engineers ended at Drumright the